Global Hydrologic Modeling

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Assimilation into global hydrology models

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Global hydrologic cycle & SWOT

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Global water & energy modeling with SWOT

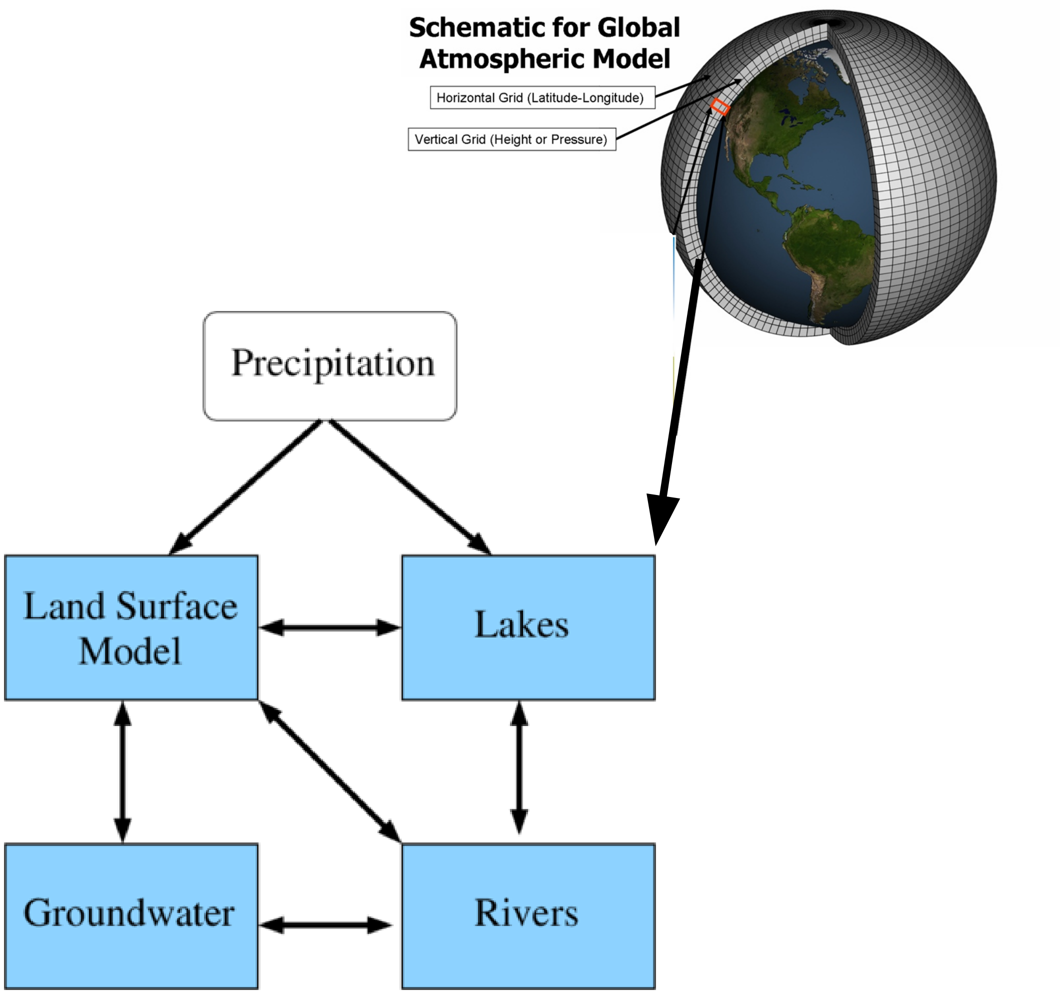
4 LSCE
5 Mines ParisTech
6 IRSTEA

SWOT-ST meeting, June 13-16, Pasadena

Global Hydrologic Modeling

Basic Background :

Hydrological cycle components in Earth Sytem/Global Climate models :



Assimilation into global hydrology models

Jet Propulsion Laboratory
California Institute of Technology

METEO FRANCE
CNRM/GAME

東京大学
THE UNIVERSITY OF TOKYO

Northeastern

JAMSTEC
JAPAN AGENCY FOR MARINE-EARTH SCIENCE AND TECHNOLOGY

Environment Canada

Integration of SWOT measurements into global hydro models

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6. **Environment Canada, Montreal, Canada**
7. **LEGOS, Toulouse, France**

Objectives

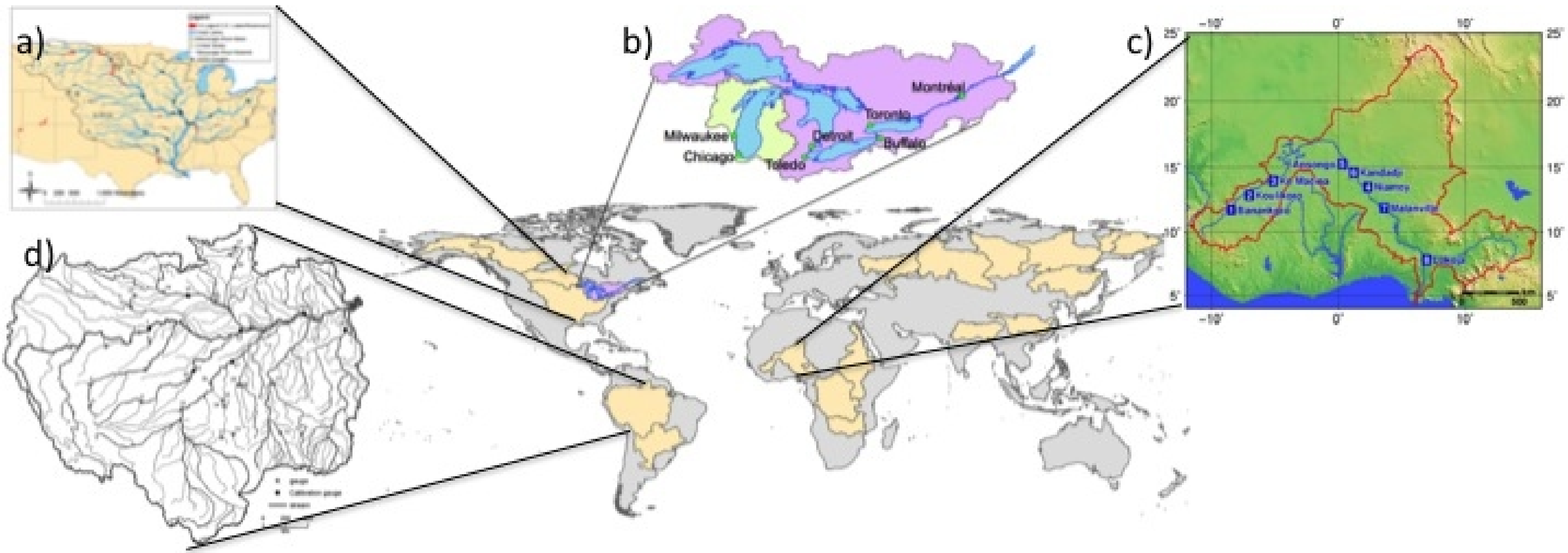
Understanding the best integration methods between expected SWOT terrestrial retrievals and existing global hydrologic/hydrodynamic models

1 How can we best **prepare for the expected SWOT continental to global measurements before SWOT even flies**? That is, how can we understand the relationships between existing **surface water variations and expected SWOT capabilities**?

2 What is the **added value of including SWOT terrestrial measurements into global hydro models** for enhancing our understanding of the terrestrial water cycle and the climate system? Are current global hydrologic models ready to ingest expected SWOT data? What SWOT variable(s) or SWOT-derived product(s) offer the best promise for integration and for data assimilation?

Assimilation into global hydrology models

Four basins in four years



The basins studied in this project benefit from existing studies:

a) the Mississippi [David et al., 2015],
b) Saint-Lawrence [Fry et al., 2014],
c) Niger [Pedinotti et al., 2012 ; 2014],
d) Amazon [Beighley et al., 2009 ; Getirana et al., 2013 ; Emery et al., 2016].

Assimilation into global hydrology models

Experimental design

Tasks		2016				2017				2018				2019			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Feasibility for applying the SWOT hydrology simulator at continental scale and alternatives	High resolution			1													
	Low resolution			1													
	Vector products			1													
	Method selected				1												
	Simulated truths				1			1				1				1	
Inter-comparison of hydro models	Design/prep.	1				1				1				1			
	Simulations	1				1				1				1			
	Multi-forcing variab.		1				1				1				1		
	Intra-model variab.		1				1				1				1		
	Inter-model variab.		1				1				1				1		
Investigating the integration of SWOT data into all hydro models	Flow				1				1				1				1
	Height				1				1				1				1
	Slope						1		1				1				1
	Width						1			1			1				1
Write scientific papers								1				1				1	1
Total number of tasks per year		12				12				12				12			

We will combine an inter-comparison framework consisting of a series of six horizontal water transfer schemes**:** **CaMa-Flood** [Yamazaki et al., 2011], **HRR** [Beighley et al., 2009], **ISBA-TRIP** [Decharme et al., 2012], **LISFLOOD-FP** [Bates and de Roo, 2000], **RAPID** [David et al., 2011], and **WATFLOOD** [Kouwen et al., 1993]. These models will be fed by runoff produced by the four land surface models of NASA's **GLDAS** [Rodell et al., 2004].

Towards a better understanding of the hydrological cycle with SWOT: from regional to global scales

A. Boone, P. LeMoigne, S. Biancamaria, S. Ricci, C. Emery

Objective: Develop a methodology for using SWOT data to improve the input parameters and the physics of the hydrological and hydrodynamic parameterizations in Earth Sysytem Models at the global scale. Anticipated outcome: better understand the potential impact of climate change on the world's water resources and potential feedbacks with the climate system.

International Collaborations :
CNES-TOSCA & NASA-ROSES: *Intercomparison of large scale hydrological models* (David et al., NASA-JPL), *Improved Global Lake Mapping and Modeling* (Y. Sheng, D. Lettenmaier, UCLA), *Characterizing the errors of multi-model ensembles* (Beighley, Northeastern U.), *DA methods and scale issues* (Andreadis, NASA-JPL)

Global hydrologic cycle & SWOT: Rivers

Work Currently Engaged :

1) Continue idential-twin OSSE data assimilation experiments with ISBA-TRIP, but with more realistic observation errors. Determine optimal spatially distributed parameters (Manning's roughness coefficient). Extension to other basins (Niger, Amazon, Mississippi, Congo, St. Lawrence)

2) Test the impact of assimilating water height anomalies as opposed to water heights

3) Explore the impact of correcting other geomorpholigical parameters (critical river height, river bed slope, or the river width)

Prospectives/Workplan for the next several years :

1) Assimilation of water heights or potentially discharge estimates derived from satellite (ENVISAT) and other hydrological/hydraulic models within ISBA-TRIP

2) Generate more realistic virtual SWOT observations (inputs from NASA-JPL/CNES)

3) Preliminary study concerning the scaling issue from large scale/coarse resolution river routing models to/from SWOT measurement (observation-space)

4) Continue extension to more basins: Global scale tests with ISBA-TRIP and new data assimilation strategy

5) Examine the possibility of correcting the trajectory of a ISBA-TRIP state variable (water resource monitoring mode)

Global hydrologic cycle & SWOT: Lakes

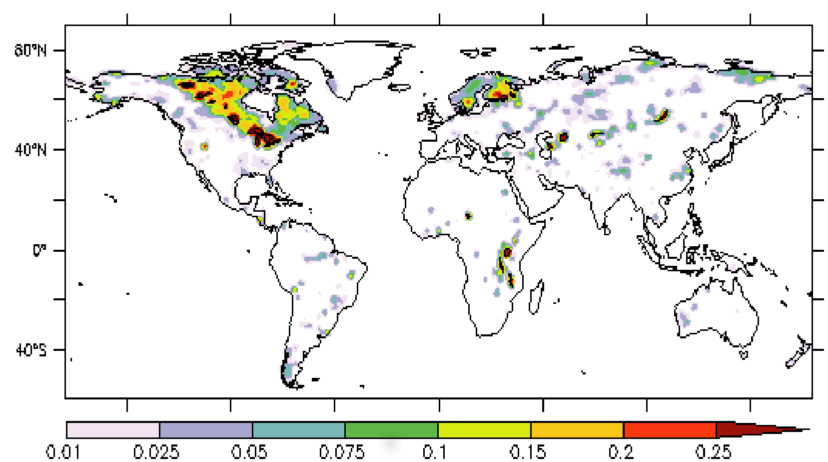
Prospectives for the next several years

1) Development of a mass water budget model based on VIC modeling (collab. HIRLAM consortium, and UCLA: D. Lettenmaier and Y. Sheng): Couple with ISBA (runoff), FLake (surface fluxes) and ISBA-TRIP (rivers and potentially groundwater interactions)

2) Evaluation and Comparison with detailed reference models (eg. TELEMAC, collab. with CERFACS) ; and inter-comparison of current state-of-the-art lake models

3) Estimate water storage of lakes at global scale using existing lake mapping: development of methodologies to optimally integrate SWOT data into the new lake mass model.

4) Improve lake surface extent in GCMs (collaboration with UCLA) to estimate impact of future SWOT data on lake water storage



Lake grid cell fraction used by FLake on the SURFEX platform in the CNRM-CM5 model.

SPAWET (SPAce altimetry for Water and Energy Transfers modeling)

C. Ottlé (LSCE-IPSL), N. Flipo (Mines-PT),

Ch. Perrin (IRSTEA-HBAN)

with the contributions of A. Jost (UMR METIS),

F. Habets (UMR METIS), A. Rivière (Mines-PT)

LSCE

Laboratoire des sciences du climat & de l'environnement

MINES ParisTech

irstea

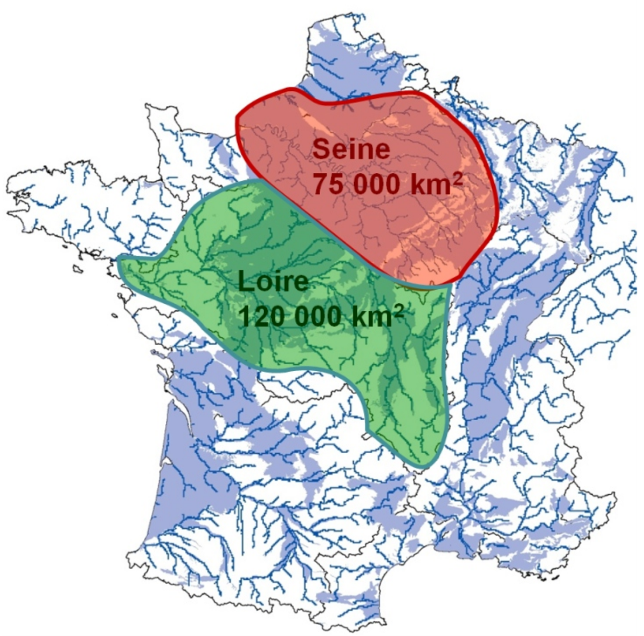
metis UMR 7619

Global water & energy modeling with SWOT

SPAWET objectives

Improve the characterization and **modelling of water and energy transfers in the atmosphere-soil-groundwater-river continuum** based on the use of **SWOT data and on a multi-model approach**

- The global land surface model **ORCHIDEE** developed at IPSL, which is a land surface physically-based model used in the global climate model LMDZ and the WRF regional atmospheric model;
- The **EauDyssée** model developed at Mines-PT and METIS, which is an integrated model designed for large basins and which couples several existing models, especially hydrology and groundwater flow;
- The **GRSD** model developed at IRSTEA, which is a parsimonious semi-distributed conceptual model designed for flow simulation.



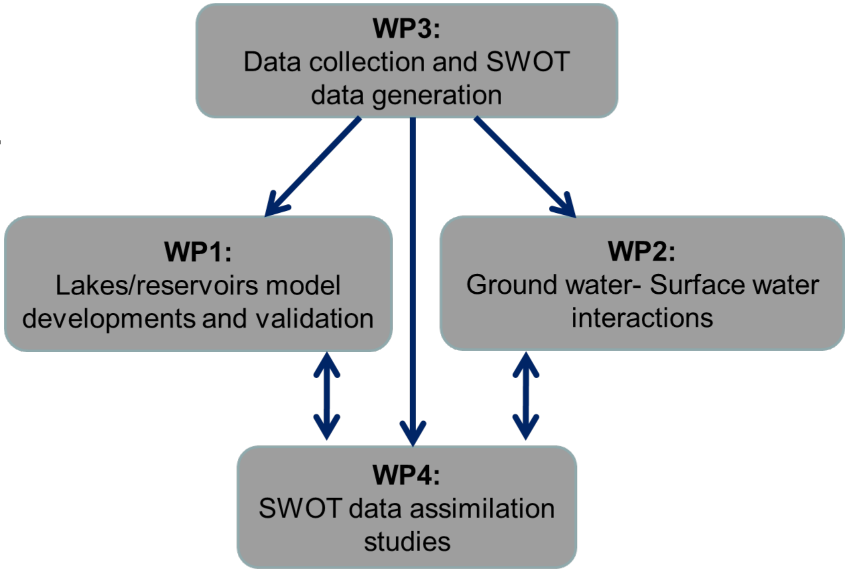
Common study basins (**Seine** and **Loire** watersheds comprising large water reservoirs) and databases ~2000 km of alluvial plains

Global water & energy modeling with SWOT

Workplan

4 Work-Packages (WP) focused on model developments, database collection, synthetic observations generation and data assimilation

- ✓ **WP1**: development of lakes/reservoirs modules in the 3 hydrological models
- ✓ **WP2:** modeling of Ground water-Surface water interactions in alluvial plains. Assess the mission capacity to retrieve GW contribution to baseflow
- ✓ **WP3**: development of databases necessary for model developments, validation and for the assimilation studies. Generation of SWOT pseudo-observations on the Seine, Loire and «La Bassée» alluvial plains as well as for a few subsystems like reservoirs.
- ✓ **WP4**: data assimilation tasks with observations (actual and synthetic) gathered in WP3, in the simulation tools developed in WP1 and WP2.



Global Hydrologic Modeling

Summary :

- Global scale projects will interact through a multi-year multi-phase intercomparison project, shared development of methodologies, provide a multi-model vision of processes and potential impact of SWOT

- Higher resolution oriented project : links with ground water : can extend to larger scale models

- SWOT has triggered initiatives to update physics : catalyst towards representing a more complete hydrological cycle at the global scale : Take advantage of global coverage of SWOT

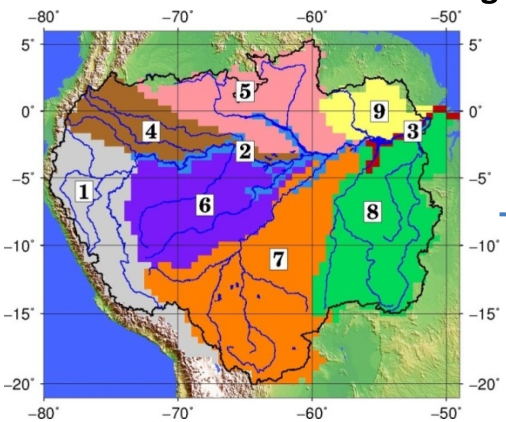
Extra

Using SWOT to correct TRIP parameters

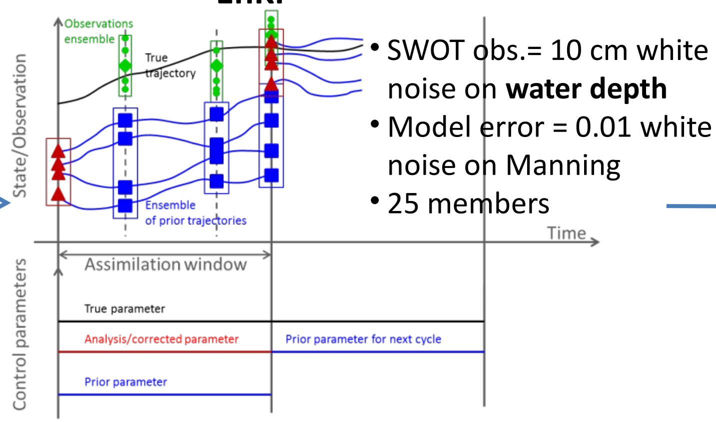
TRIP parameters sensitivity analysis (PhD work : C. Emery, LEGOS)

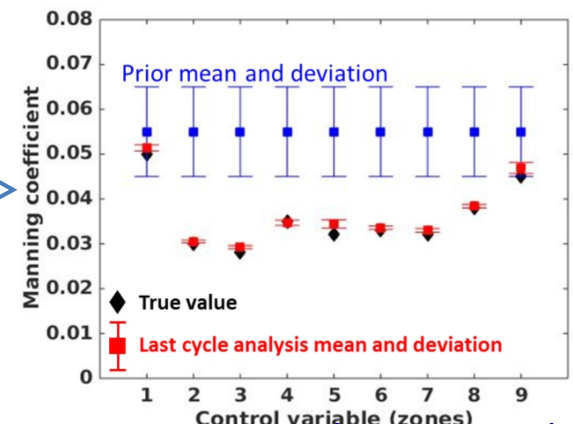
- **SWOT water elev. (and anomalies!) could correct river geomorpholgical parameters, SWOT discharge product could correct groundwater time constant**
- Build EnKF assimilation platform to correct TRIP parameters: begin with Manning coeff:
- Testing more complex configurations: adding precipitation error to model error (degrade Manning retrieval), using SWOT water elev. anomalies instead of water depth (bathy unknown), test cases with and without floodplains… tests still ungoing…

Zones # with constant Manning



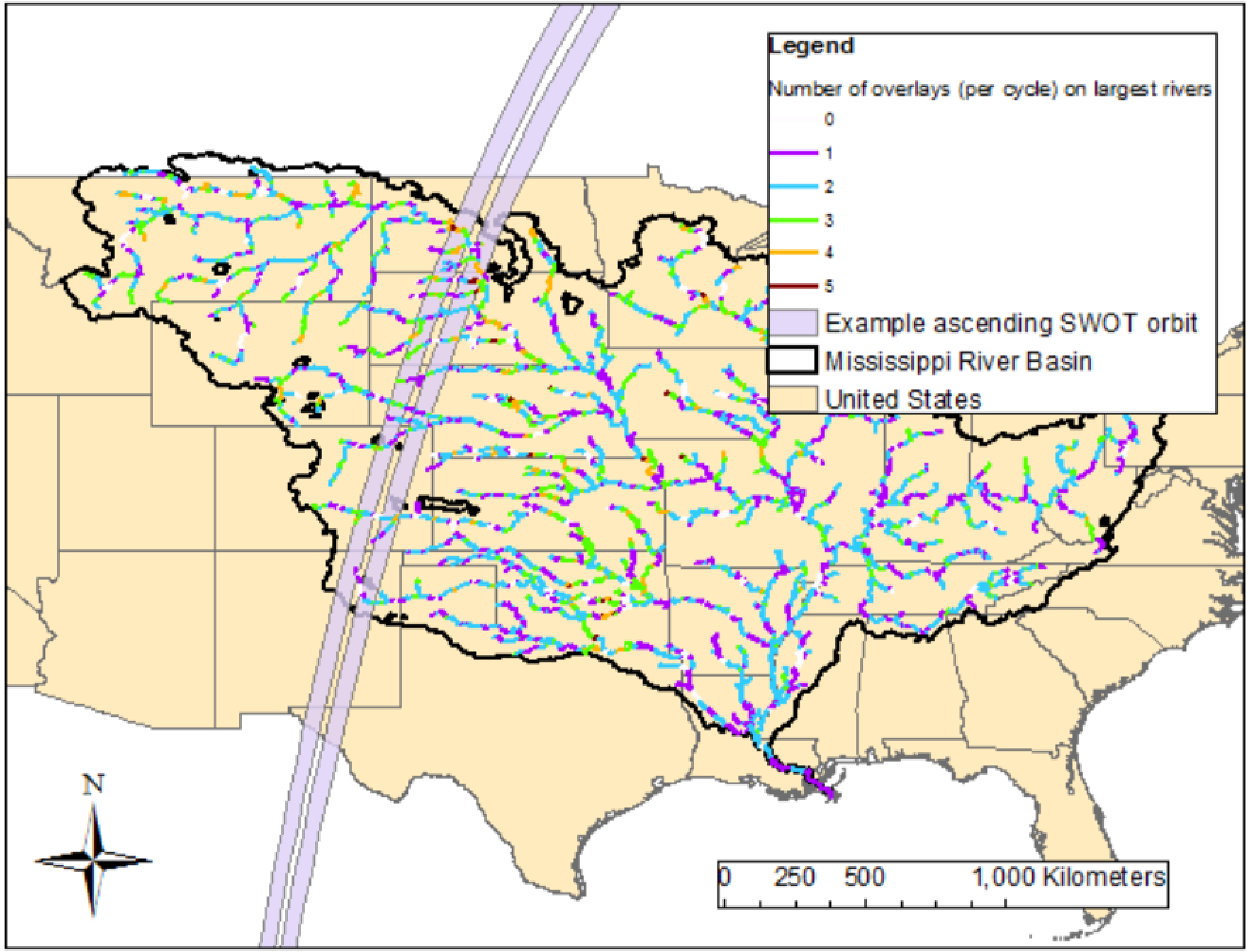
EnKF





(collaboration with: S. Biancamaria , A. Boone, P.-A. Garambois, S. Ricci, M. Rochoux, B. Decha
A. Paris, S. Calmant)

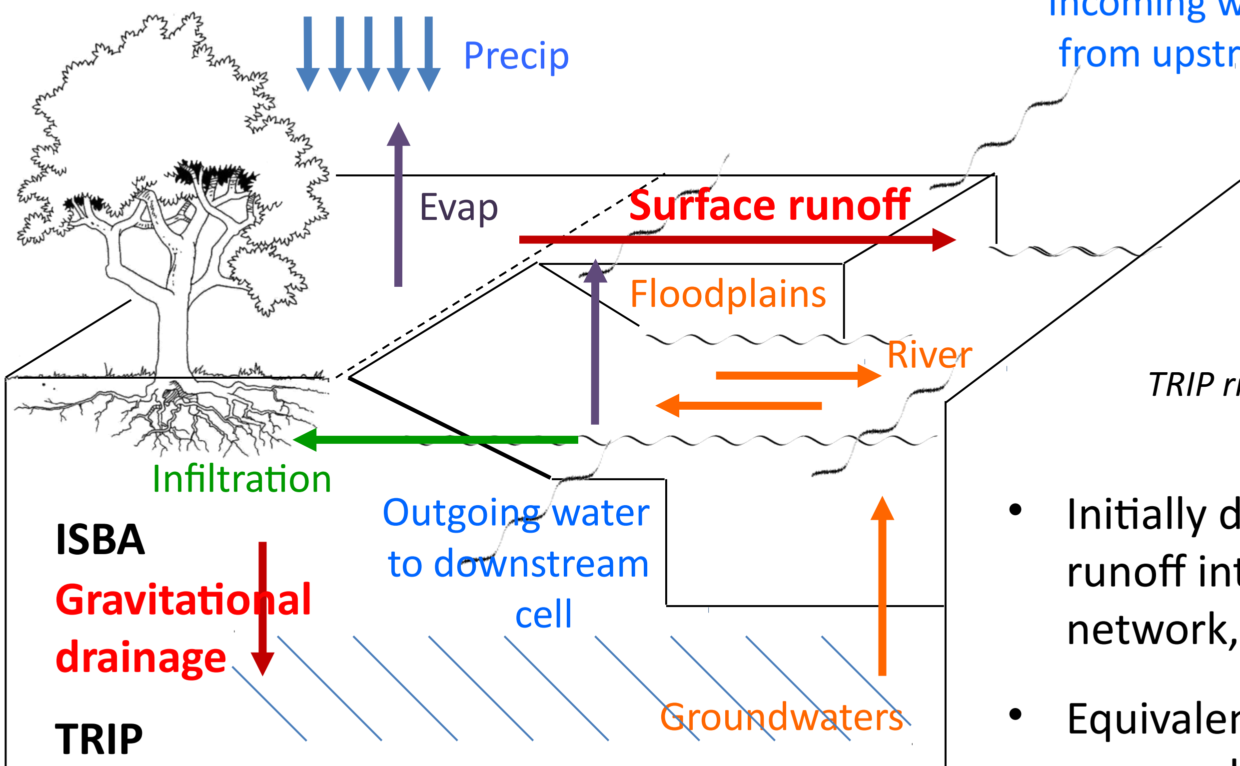
Preliminary results



Preliminary work has started to sub-sample continental-scale model outputs based on a tentative SWOT trajectory. This endeavor was performed as community effort and is openly accessible to members of the SWOT Science Team.

Regional/global Land Surface Model: ISBA-TRIP model

The ISBA-TRIP model



TRIP river routing network over the Amazon

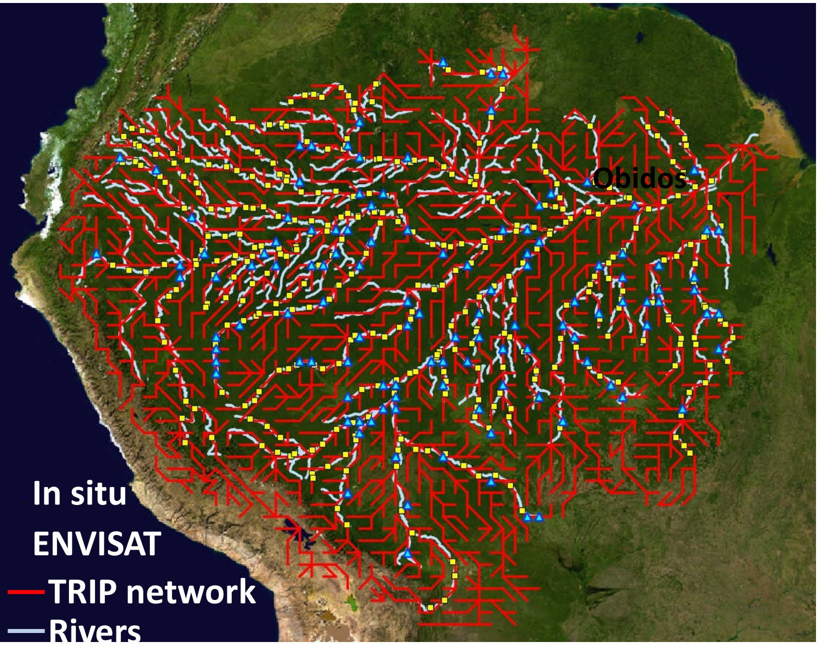
Estimation of:

- **River water level,**
- **River discharge**
- **Floodplain water storage**

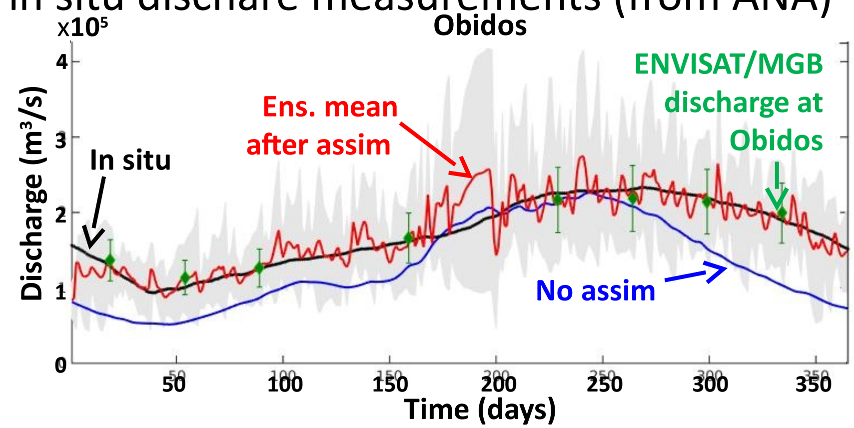
- Initially designed to convert surface runoff into discharge over a global river network,
- Equivalent river with rectangular section + groundwater + floodplain reservoirs,
- Variant flow velocity calculated with the Manning equation
- Run at 0.5°x0.5° (~50km x 50 km)

2. Using altimetry to correct TRIP state

- Purpose: test discharge product potential to improve global daily discharge from TRIP

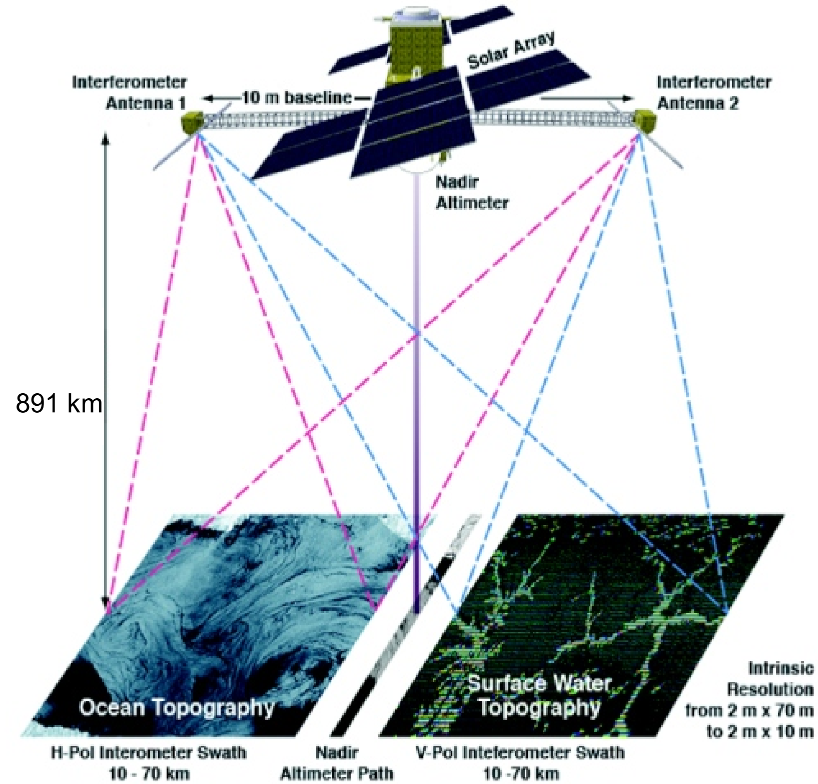


- Observation: discharge derived from Envisat elevation and rating curve (using MGB model discharge, Paris et al. 2016) + 20% white noise
- Estimated ENVISAT/MGB discharge:
  - repeat period : 35 days (and more due to missing data)
  - No global coverage (nadir altimeter)
  - Real data (not OSSE), but using calibrated (with in situ meas.) MGB model discharge
- EnKF to correct river storage (model error: 25% on precip + few % white noise on TRIP storage)
- Truth = in situ dischare measurements (from ANA)



- Different length of observation localization has been tested -> needed to avoid spurious corellation but limit DA impact
- At Obidos, RMSE no assim/in situ=30%, RMSE mean ens. Assim/in situ=13%
- 100 members ensemble
- Need to test other obs. and model errors...


SWOT
Surface Water Ocean Topography


Solar Array
Interferometer Antenna 1
10 m baseline
Interferometer Antenna 2
Nadir Altimeter
891 km
Ocean Topography
Surface Water Topography
Intrinsic Resolution from 2 m x 70 m to 2 m x 10 m
H-Pol Interometer Swath 10 - 70 km
Nadir Altimeter Path
V-Pol Inteferometer Swath 10 -70 km